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TECHNICAL MANUSCRIPT 426

LABORATORY STUDIES OF MOSQUITO FLIGHT: III. EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON FLIGHT ABILITY OF FEMALE AEDES AEGYPTI

Wayne A. Rowley
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DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland 21701

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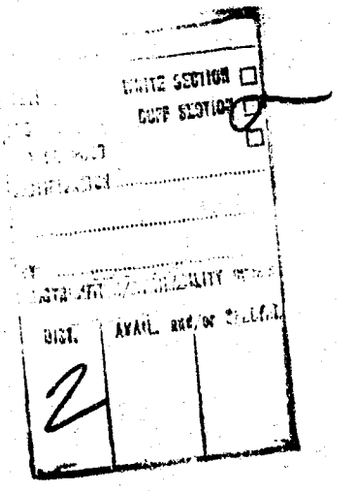

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LABORATORY STUDIES OF MOSQUITO FLIGHT: III. EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON FLIGHT ABILITY OF FEMALE *AEDES AEGYPTI*

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Project 1C522301A059

October 1967

ABSTRACT

The influence of temperature and relative humidity on the flight performance of tethered virgin female Aedes aegypti was investigated. Mosquitoes of similar age were flown to exhaustion on flight mills at various temperatures and relative humidities. Parameters measured were distance flown, duration of flight, speed of flight, initial weight of mosquitoes, and live weight lost during exhaustive flight.

The temperature range at which sustained tethered flight occurred was 15 to 32 C. Temperature extremes at which flight was possible were 10 and 35 C; however, performance was minimal in both duration and distance at these temperatures. The optimal temperature for flight was 21 C. Mosquitoes flew farther at 15 C than at the commonly reported optimal temperature of 27 C. In general, flight performance was greater below 27 C.

Relative humidity within 30 to 90% had no demonstrable influence on flight performance at any temperature studied except at 32 C, where 30% had a marked limiting effect on mosquito flight.

I. INTRODUCTION

Optimal temperature and humidity for adult mosquito longevity and biting activity have been well established, but no data are available on optimal conditions for flight activity. It is generally accepted that temperature and relative humidity (RH) profoundly influence the behavior and activity of adult mosquitoes, but authors disagree considerably as to how these environmental factors affect mosquito activity. The exact effects of either or both factors on mosquito flight can only be generally estimated because it is difficult, if not impossible, to separate the effects of one from the other when dealing with any biological entity. Christophers[1] reports the temperature effect as being "rather complex" with regard to mosquitoes, affecting feeding primarily through a general influence upon the activity of the organisms; he concluded that mosquitoes will attempt to bite at any temperature at which they are physically capable of doing so.

Most available literature concerning the effects of temperature and RH on Aedes aegypti deals with the biting activity of the species at various temperatures. Conner[2] found that A. aegypti was most active at 28 C, a temperature considered to be optimal for the species. The majority of authors consider that this species has an optimal temperature range between 27 and 32 C and all vital activities are retarded between 17 and 25 C.

Christophers[1] states that, for routine testing, 70 to 90% RH at 25 C will ensure maximal and standard testing (biting) results. However, he also indicates that an extremely high humidity has an inhibitory effect on feeding, especially at high temperatures. Lumsden[3] reports that RH is of negligible importance with regard to biting by mosquitoes.

The present study was designed to determine the optimal temperature and RH requirements for flight activity in virgin female A. aegypti. A secondary objective was to investigate the range of both temperature and RH at which sustained flight was possible.

II. MATERIALS AND METHODS

Female Aedes aegypti (Rockefeller strain) were the test organisms. Larval rearing, handling, and determination of pupal and adult age were identical to that reported by Rowley and Graham.[4] Mosquitoes used in flight studies were held as adults in 1-pint ice-cream cartons at 27 C and 80% RH and provided a 0.3 M sucrose solution in saturated cotton pads. These conditions had previously been demonstrated to be optimal

for adult longevity.* Four to 12 mosquitoes were tested each day for 3 consecutive days at a prescribed set of conditions. Mosquitoes were removed from a carton and flown to exhaustion on flight mills at 10, 15, 18, 21, 27, 32, and 35 C. The RH at each temperature was regulated at 30, 50, or 90%. Limitations in the regulation of RH in our controlled environmental laboratory restricted flights at 30% RH to 21, 27, and 32 C. Humidity could not be adequately regulated for flight studies at lower levels. The chamber was allowed ample time to reach a state of equilibrium at a designated set of conditions before flight tests were undertaken.

The effect of age on the flight ability of A. aegypti is striking. Flight performance is maximal in the first 2 weeks of adult life, but no difference in flight ability is detectable among mosquitoes that are within 1 week of age.[4] Therefore, these tests were conducted using mosquitoes ±1 week of age. This afforded a comparison of the flight performances of similarly aged individuals under different environmental conditions.

Constant surveillance of temperature and humidity was maintained during all flights. Humidity recorders** were employed to monitor RH variation throughout the test chamber and in each flight mill canopy. Temperature sensing devices were also employed. Once established, temperature remained at ±1.5 C and RH fluctuations were less than ±5%, except at the 30% level where ±5 to 10% was maintained. Details of the flight mill system and techniques for flying mosquitoes are presented in a previous paper.[5]

III. RESULTS

The mean preflight (live) weight and mean weight lost during exhaustive flight by mosquitoes flown at the different temperatures and humidities are presented in Table 1. The initial live weight of mosquitoes had no observable effect on flight ability. Weight loss during exhaustive flight was dependent on the length and duration of flights and was apparently independent of the environmental conditions. Weight loss during flight was strikingly similar at each temperature tested regardless of RH. Above 18 C, weight loss increased slightly at 50% RH even though the distance flown was slightly less than at 90%.

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* W.A. Rowley, unpublished data.

** Speedomax G Recorder, Leeds and Northrup Co., Philadelphia, Pa.

TABLE 1. AVERAGE MOSQUITO WEIGHTS BEFORE AND WEIGHT LOSSES AFTER FLIGHTS AT VARIOUS TEMPERATURES AND RELATIVE HUMIDITIES[a]/

Temp., C	Initial Live Weight ± SE, mg		Weight Loss in Flight ± SE, mg	
	90% RH	50% RH	90% RH	50% RH
35	3.493±0.125	3.306±0.117	0.090±0.011	0.181±0.036
32	3.829±0.119	3.591±0.140	0.178±0.042	0.225±0.033
27	3.039±0.103	3.886±0.121	0.666±0.073	0.724±0.059
21	3.706±0.099	3.637±0.091	1.016±0.076	1.116±0.066
18	2.950±0.068	3.302±0.065	0.642±0.054	0.651±0.055
15	3.307±0.166	3.726±0.133	0.461±0.070	0.424±0.058
10	3.473±0.100	3.679±0.086	0.018±0.005	0.011±0.002

a. All data are averages for 12 mosquitoes.

A histographic representation of the flight performance (distance flown) by female A. aegypti at each temperature and the various RH's is presented in Figure 1. Temperatures of 10 and 35 C clearly represent the extreme limits at which tethered flight is possible in this species. The optimal temperature for flight was 21 C. Flights at 32 and 35 C were shorter than expected and indicated either a loss of flight ability or a "reluctance" to fly at these temperatures. The performance of mosquitoes at 21 and 27 C was similar at all three humidity levels. At 32 C, a reduction in RH from 50 to 30% resulted in a marked decrease in flight performance, thus indicating a definite negative response to low humidity at this and, probably, higher temperatures. However, this was the only case studied in which humidity had an obvious influence on flight.

Flight duration, like the other variables, was independent of the humidity levels tested. Maximal duration of flights at all three humidity levels occurred at 21 C. At 21 C and 30% RH, the average duration of flight was 494 minutes, which was 22 minutes longer than the mean duration of flights at the same temperature at 50% RH and 60 minutes shorter than the mean duration of flights at 21 C and 90% RH. At most temperatures, the duration of flight was slightly greater at the higher humidities, but in no case was the difference sufficient to be of statistical significance. Table 2 shows the mean duration or time of flight at the different temperatures at 50 and 90% RH.

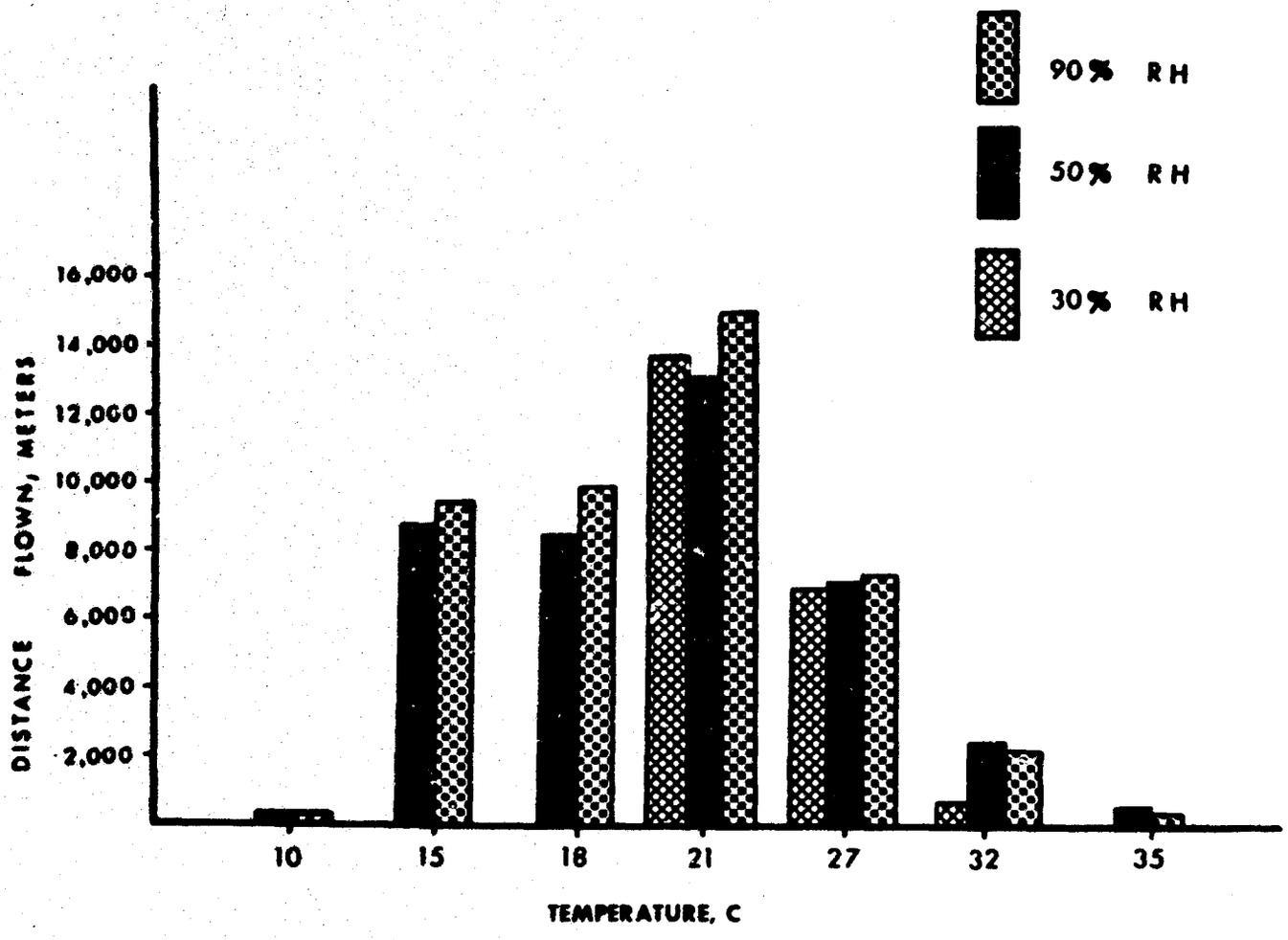

Figure 1. Average Distance Flown by Female *Aedes aegypti* at Different Temperatures and Relative Humidities. Mosquitoes were flown on flight mills in the laboratory.

TABLE 2. MEAN DURATION OF FLIGHTS BY FEMALE AEDES AEGYPTI AT 50 AND 90% RELATIVE HUMIDITY AND DIFFERENT TEMPERATURES[a]/

Temp., C	Duration of Flight ± SE, minutes	
	90% RH	50% RH
35	17.6± 1.6	29.9± 4.2
32	80.8±16.4	70.2± 8.8
28	258.3±24.9	228.1±18.9
21	554.2±58.1	472.0±30.3
18	361.9±32.6	322.7±32.1
15	414.1±38.6	376.3±47.9
10	30.0± 2.2	18.1± 1.9

a. All data are averages for 12 mosquitoes.

Figure 2 represents the average speed of flight (meters per minute) of mosquitoes flown at 50 and 90% RH and various temperatures. Flight speed was similar regardless of the temperature from 15 to 32 C at 90% RH. However, at 50% RH, flight speed increased gradually as temperature increased to 32 C. At 32 C, the average flight speed was substantially higher at 50% (34.1 meters per minute) than at 90% RH (28.0 meters per minute). Speed decreased sharply when the temperature was elevated from 32 to 35 C. Flight speed was slightly higher at 35 C than at 10 C regardless of RH.

IV. DISCUSSION

The optimal conditions for all vital activities of mosquitoes have been assumed by many authors to be 27 C and 80% RH. Our studies indicate that such is not necessarily the case, at least if the tethered flight performance of adult female A. aegypti can be accepted as a vital activity. Apparently, flight is more readily undertaken and sustained at temperatures below the optimal level than at temperatures above it.

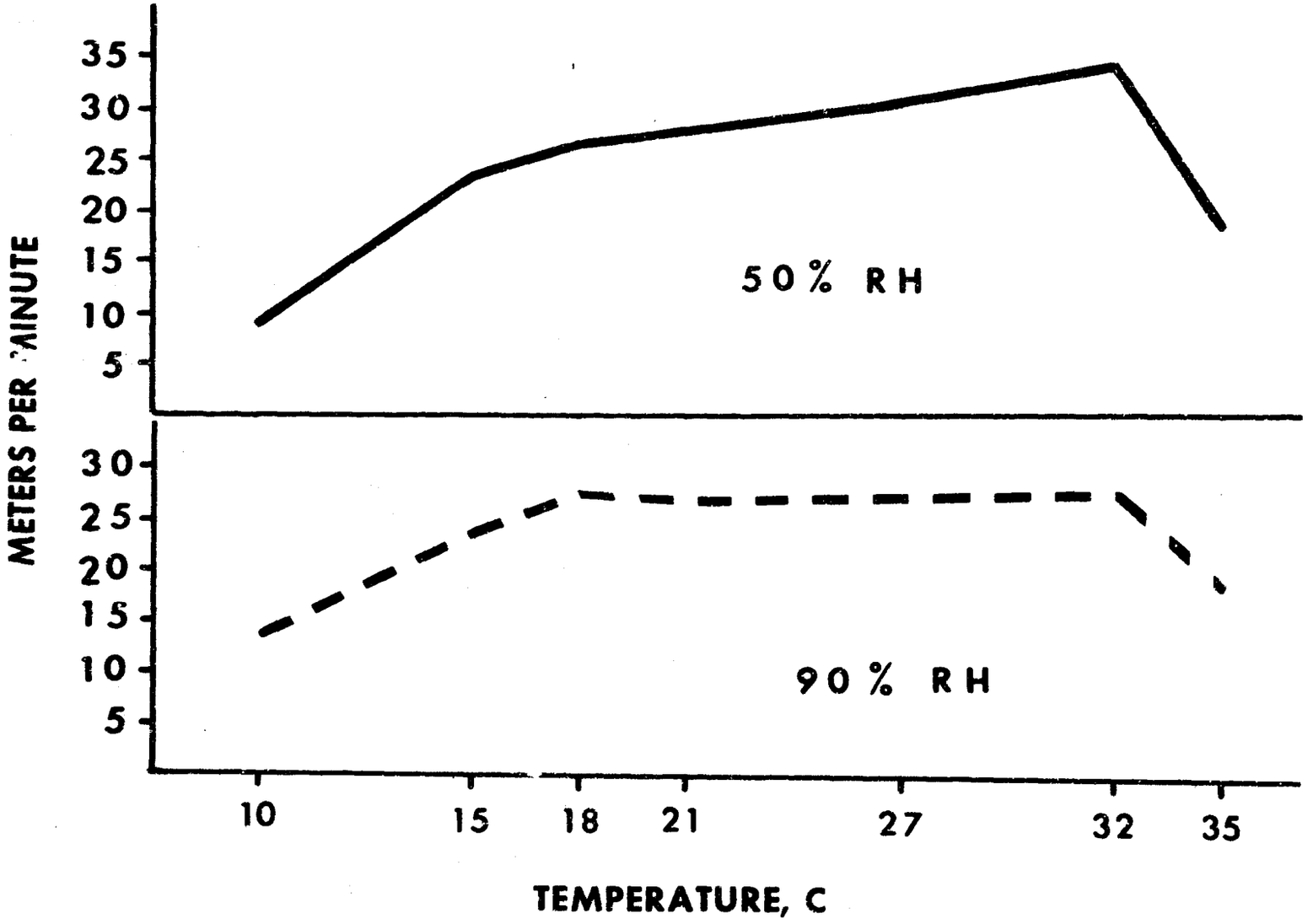

Figure 2. Average Flight Speed of Female Aedes aegypti Flown at 50 and 90% Relative Humidity and Different Temperatures.

Published data[6,7] indicate that the temperature of the internal thorax (flight muscle) of flying insects increases from a few to several degrees above ambient temperature. If this is correct for mosquitoes, flight at lower temperatures would be enhanced, but at the higher levels it would probably be impeded. The unexpectedly strong flight abilities of this insect at 21 C and even at 18 and 15 C could possibly be the result of this phenomenon.

RH, within the 30 to 90% range tested, had very little demonstrable effect on the flight activity of virgin female A. aegypti, except for a depression of flight ability at 32 C and 30% RH. If temperature conditions were suitable, mosquitoes flew well at all RH's, and performance at any given temperature was independent of the RH. These results are in agreement with the findings of Thomson,[8] who found that changes in humidity of as much as 40% within the range of 30 to 85% have little or no effect on the behavior of the mosquito Culex fatigans.

Yurkiewicz and Smyth[7] found the wing-beat frequency in the blowfly Phaenicia sericata increased with increases in temperature between 15 and 30 C. This is somewhat in contrast to the tethered flight performance of our mosquitoes in that flight performance at the lower temperatures exceeded that at 27 and 32 C. Below 21 C, mosquito flight performance was slightly better at 90% RH than at 50% RH. However, at 27 C and above, flight performance was slightly higher at the lower humidities. The mean distances flown by 36 mosquitoes at 21 C were 14,419, 13,244 and 13,517 meters at 90, 50, and 30% RH, respectively. This clearly indicates that, at this temperature, flight is totally independent of RH at least between 30 and 90%.

Statistical analysis of data, using a two-error split plot with a completely randomized design for performance at the different temperatures and at 50 and 90% RH, indicated an absence of humidity effect. However, there was a strong indication of interaction between the two variables.

It was not possible to evaluate the effects of RH below 30% or above 90%. It seems reasonable to expect more pronounced effects of either or both conditions near the limits of tolerance. At the same time; however, extreme conditions are rarely, if ever, imposed in the laboratory and are of limited significance in nature.

Gaul[9] reported that the wing-beat frequencies of two species of Vespula were independent of temperature from 8.5 to 28 C. Platt, Collins, and Witherspoon[10] found 70 to 80% RH was optimal for Anopheles quadrimaculatus, but sharp avoidance reactions were noted at both low and high humidities. This could well be the case with A. aegypti flight ability; however, there is no apparent optimal humidity level.

Temperature, unlike RH, appears to markedly influence flight ability in these mosquitoes. The wide temperature range from 15 to 32 C at which sustained tethered flight is possible validates this conclusion. In view of the results obtained, it appears that females of this species might be much better fliers in the cooler hours of the day, such as early morning or evening. This would be especially important in areas where extremely high daytime temperatures prevail.

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14. Key Words

Mosquitoes *Flight
*Aedes aegypti Temperature Relative humidity

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